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ON THE

STRUCTURE OF THE HUMAN EAR,

AND ON

THE MODE IN WHICH IT ADMINISTERS TO THE PERCEPTION OF SOUND.

PART III.

BY

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On the Functions of the Membranous Labyrinth and of the Semicircular Canals.

IN my previous papers I have proceeded on the assumption that, in those animals whose auditory apparatus includes a cochlea, the perception of aërially conveyed sounds is occasioned by the alternate ebb and flow of the *liquor Cotunnii* from the cochlear aperture, along the scalæ, to the vestibular aperture, and *vice versâ*; and my efforts have been mainly directed to pointing out the mode in which this alternate motion of the aural liquid is mechanically effected.

It is clear that this motion can in no degree be dependent upon the action, or even upon the existence, of the membranous labyrinth or of the semicircular canals. Whether it is capable of affecting the nerves expanded within the former is a different question, and one which will require consideration; but up to this point I have made no attempt towards explaining the functions, or accounting for the strange form exhibited by the membranous labyrinth. To this part of the subject I now propose to address myself.

Upwards of forty years have elapsed since the late M. Flourens demonstrated in the most conclusive manner, by means of experiments performed upon living subjects, that the semicircular canals in birds and in mammalia have functions totally unconnected with the sense of hearing.

The researches to which I refer are contained in two memoirs read to the French Academy of Sciences in the year 1828, and inserted in the *Mémoires* of that body published in 1830; the first of which memoirs relates to the case of birds, the second to that of mammalia. Of the first, a Report* was drawn up by the illustrious Cuvier, to whom, with MM. Portal and Duméril, the memoir was referred, and in whose presence the various experiments were repeated.

It results from M. Flourens's experiments, that in birds and in mammalia the nerves of the semicircular canals, whatever other functions they may possess, unquestionably exercise this, viz. of regulating the motions of the head, and of the animal generally, of enabling it to preserve its equilibrium and to move steadily in a given direction. No general description, however, can give an adequate idea of the remarkable phenomena developed in these memoirs.

I shall therefore in the first place describe in considerable detail the experiments and their results, which appear to have attracted very little attention from writers on aural anatomy†.

I shall next show how the effects described may be accounted for—a branch of the subject upon which M. Flourens has not entered.

I shall finally consider the question whether the functions thus shown to be possessed by the part of the animal economy under consideration are or not exercised concurrently with others of a totally different character—whether, in short, the semicircular canals are to any, and what, extent operative in producing perception of sound.

I. The semicircular canals in birds, as in mammalia, are three in number, two vertical and one horizonal, of which the largest is vertical and superior. "The smallest is situated horizontally. The canalis minor, or third of the series, is vertical. They contain corresponding tubes of vascular membrane; and they also possess enlarged ampullæ, on which the nerves are distributed in the same manner as in mammalia." (Cyclopædia of Anatomy and Physiology, vol. i. p. 308.)

The superior vertical canal is described as directed from behind forwards, while the inferior canal takes the opposite direction.

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* *Ann. de Chim. et de Phys.* 1828. To a reference to this Report contained in the article on Sound in the *Encyclopædia Metropolitana* I am indebted for having my attention called to the subject of it.

† I find no mention of them in the admirable and very complete *résumé* of the subject drawn up by Mr. Wharton Jones for the 'Cyclopædia of Anatomy and Physiology' eight years after the publication of Cuvier's Report; and I do not find the omission repaired in any later treatise on the subject which has come under my notice. Mr. Jones appears to have been acquainted with some earlier speculations of M. Flourens. See 'Cyclopædia,' vol. ii. p. 570.

All the canals are enveloped in a thin bony coating (*tunique osseuse mince*).

When the horizontal canal on the left side of a pigeon was cut, a slight movement of the head from right to left and from left to right exhibited itself. This motion continued only for a short time, after which the animal recovered its usual demeanour (*allure*). Its senses, its intelligence, and the equilibrium of its movements remained perfect.

When the horizontal canal of the right side of the same bird was cut, the horizontal motion of the head suddenly reappeared, but with a rapidity and impetuosity such that the animal, entirely losing its equilibrium, fell, and for a long time rolled upon itself without being able to stand erect.

The violent motion of the head ceased after a time, and so long as the animal continued in repose its head continued in repose also; but the moment the animal moved, the motion of the head recommenced, and that motion always became stronger in proportion to the rapidity with which the animal attempted to move itself.

Thus, when standing still, the animal preserved its equilibrium; it lost it when it tried to walk; it lost it still more when it tried to walk quickly; it lost it entirely when it tried to fly. The animal feared to move: it saw well; it could still hear; it preserved all its instincts and all its intelligence; it ate and drank spontaneously, though with great pain.

M. Flourens observed this bird for a whole year. The wound in the head healed completely; the bird became very fat; but the motion of the head, the rolling upon itself, and the loss of equilibrium upon any sudden movement, however slight, always exhibited themselves.

When the inferior vertical canal on the left side of another pigeon was cut, there immediately ensued a slight but rapid movement of the head from below upwards and *vice versâ*; but this only continued an instant. The animal, when left to itself, could hold itself erect: it walked and flew regularly, except that it experienced from time to time a sharp and sudden motion of the head backwards, which for the moment disturbed its equilibrium and went sometimes almost to the point of throwing it over on its back; at the end of some moments, however, this movement dissipated itself, or only reappeared after longer intervals.

When the inferior vertical canal on the right side of the same bird was cut, the vertical movement of the head reappeared with a violence and impetuosity in all respects similar to those exhibited by the horizontal movement when the horizontal canal on both sides was cut. The movement up and down was almost continual: sometimes the head bent a little from one side to the other, as if to make a turn half round (*comme pour faire un demi-tour*); but the dominant direction of the movement was always from below upwards and *vice versâ.*

When the pigeon was stationary, its equilibrium was maintained; and the better to preserve it, the animal rested its head on the ground; and it was always the top of the head bent back (*sommet de la tête renversée*) which was so supported.

The motion of the head always increased in activity along with the other motions of the body, and, on the other hand, disordered the latter to such an extent that all regular movement was impossible.

In this experiment, unlike what occurred in the former when the two horizontal canals were cut, the animal could neither walk nor fly. When thrown into the air, after some incoherent movements of its feet and wings, its whole frame stiffened, and it fell like an inert mass.

The animal never turned upon itself as when the horizontal canals were cut; but often, in its own despite, it fell over backwards upon its tail, and sometimes rolled for a long time in this direction.

This pigeon was kept for nearly a year. It ate and drank voluntarily (*de lui-même*), although it had infinite difficulty in governing its head for a moment so as to seize its food and drink. It could never fly; when it tried to walk at all fast, it fell and rolled on its back. Almost always it remained in the same place, the top of its head turned back resting on the ground or against the bars of its cage. The vertical movement of the head was always maintained, and always with almost equal intensity.

When the superior vertical canal on the left side of a third pigeon was cut, there immediately resulted a slight but rapid movement of the head from above downwards, and *vice versâ.* This movement was of short duration, but soon recurred. Left to itself, the animal walked steadily or held itself erect; though liable from time to time to tumble forward.

When the corresponding canal on the right side of the same bird was cut, there instantly occurred a quick and violent movement of the head from above downwards and *vice versâ.* This movement was accompanied, as in the former case, by disturbance of equilibrium, which, in like manner, ceased when the animal was in a state of repose, and recurred with its motion, increasing in rapidity when the latter was accelerated.

In all the experiments, when two corresponding canals were cut, there resulted rolling of the eyeball and a convulsive motion of the eyelids.

When the third pigeon was operated upon, it did not roll sideways as in the case of the first, or tumble backwards as did the second, but tumbled forwards.

This bird was also preserved for a year.

A fourth pigeon had all the canals cut in both ears. There resulted immediately an impetuous (*fougueux*) and confused motion of the head in every direction—from above downwards, from below upwards, from right to left, and from left to right. "Ce mouvement était d'une violence inouie." It so disturbed the equilibrium of the animal that it could only obtain some moments of repose by resting its head on the ground.

M. Flourens tried the effect of removing the osseous covering of the canals, leaving, I presume, in each case the lining membrane untouched, so as to prevent the lymph contained in the labyrinth from making its escape. None of the effects before described occurred in this case; but they exhibited themselves, though in a less degree, when the membranous labyrinth of the respective canals was *pricked*, the phenomena in each case being the same in character as when the corresponding part of the apparatus was cut through—thus showing that the phenomena above described were owing entirely to the action upon the [so-called] acoustic nerve expanded upon the membranous canals.

The same experiments were repeated upon other pigeons, upon pullets, sparrows, finches, yellow-hammers, linnets, tom-tits, &c. The results, though varying in intensity, were always identical in character.

After adverting to the circumstance of the experiments having been repeated in the presence of M. Duméril and himself, M. Cuvier gives his testimony concerning them in the following terms:—

"La section de chaque canal a produit effectivement les mouvemens bizarres qui sont annoncés dans le mémoire. Quelque surprenans, quelque inexplicables que sont ces faits, nous ne pouvons les révoquer en doute."

The semicircular canals in mammals are enclosed in the petrous bone, the hardest and the most compact which their structure exhibits. In order that experiments similar to those practised upon birds might be extended to mammals, it was necessary in part to remove this bone; and on this account M. Flourens selected as the subject of his experiments young rabbits, animals which possess from birth the faculty of locomotion, at the same time that the bony envelope of their canals does not attain at that early stage of their career its full hardness.

For operating on the horizontal and posterior vertical canals, rabbits of two months old were selected. In the case of the anterior vertical canal, which presented greater difficulty, the age had to be reduced to fifteen days.

In the first two cases the results of the experiments, with some unimportant variations, were the same in character as those of the corresponding experiments upon birds.

When one horizontal canal only was cut, the head of the animal in repose was always to the side of the section; but when both horizontal canals were cut, the head resumed its natural position. In the latter case, not merely the head, but the fore legs, and, indeed, the entire fore part of the animal, partook of the oscillatory movement from right to left and *vice versâ.*

It was found difficult to operate on the anterior vertical canal without injuring the brain, by which the results of the experiments were complicated with those flowing from the lesion of the latter. In the few cases in which this cause of error was avoided, the results of the experiments were precisely similar to those of the corresponding experiments on birds.

It is consolatory to think that the rabbits experimented upon did not seem to suffer the pain which was experienced by the pigeons; nevertheless M. Flourens does not appear to have succeeded in keeping alive the former beyond a month in one case, and a week in another.

II. Assuming that experiments operated on the semicircular canals of the human ear resembling in character those performed by M. Flourens upon pigeons and upon rabbits would be attended by like results, I now proceed to explain how the occurrence of such results may be accounted for.

The membranous labyrinth, I conceive, must be regarded in the light of a delicate balance, which, being suspended in the perilymph contained in the vestibule and semicircular canals, upon each movement of the head changes its position in the irregularly shaped bony cavity within which it is confined, and is thus enabled, in a manner presently to be described, to transmit to the mind or subordinate directing principle such intelligence respecting the motions of the head as may be necessary with a view to their regulation, variation, and maintenance.

The membranous labyrinth is supported by nervous filaments, which, leaving the inner wall of the osseous labyrinth, after traversing the perilymph, penetrate within as well the membranous vestibule (sinus communis) as the ampullæ, with one of which each canal is provided, and diffuse themselves over these parts of the membranous labyrinth to the exclusion of every other.

The experiments of M. Flourens show that motion of the head forwards is governed by the anterior vertical canals, motion backwards by the posterior vertical canals, while motions to the right and left are governed by the horizontal canals.

I apprehend that these effects are produced through the exclusive agency of the ampullæ, each of which (in form, as in function, resembling the bubble of a spirit-level) by its position indicates the motion of the head in the direction to which it has reference.

When the head moves, the membranous labyrinth will not implicitly follow its motion, but will lag somewhat behind, on account of the superior specific gravity of the endolymph as compared with the perilymph.

Thus, if the head move to the left, that end of the membranous ampulla of the left horizontal canal which is *nearest* to the vestibule will be forced into the corresponding portion of the surrounding osseous ampulla, the hard bony substance of which, pressing on the flexible integument of the membranous ampulla near its flask-like termination, will *constrict* the latter so as to cause the liquid contained within it to move in the direction of its length. Such a motion of the endolymph in the ampulla will necessarily excite the nerves expanded within it*; and we can thus see how the change in the position of the head will be at once signalled to the brain.

The movement of the head (to the left) which we have been considering will produce in the right ear effects opposite to those which have just been described. In this case the end of the membranous ampulla of the right horizontal canal which is *furthest* from the vestibule will be forced into the corresponding portion of the surrounding bony ampulla. Consequently the end of the membranous ampulla which is furthest from the vestibule will in this case become constricted, and the flow of the endolymph will take place in a direction (with respect to the vestibule) opposite to that which it took in the former.

A second contemporaneous signal may thus be expected to be transmitted, which, although effected in a somewhat different manner, will have the same object as the signal from the left ear which we have just been considering, viz. to indicate that an exertion of the muscles by which the head is bent to the right will be necessary in order to restore the head to an erect position.

Such I conceive to be the mode of operation, and the special function, of the horizontal canals in the perfect organ when the head is moved to the left.

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* "The filaments form a fine network on the outside of the ampullæ, and then piercing their parietes, are raised up within into a kind of crescentic screen, in order probably that they may be more exposed to the impulse of the vibrations descending along the aqueous endolymph of the semicircular tubes."—Penny Cyclopædia, 1837, vol. ix. p. 238. This description applies primarily to cartilaginous fishes, but is given as illustrative of what occurs in the case of the "superior animals, man included."

The application of the same principle of explanation to the same canals when the head moves to the right, and to the vertical canals when the head moves backwards or forwards, is so obvious that it need not now be dwelt upon.

When the head is held erect, or probably when recumbent in a horizontal position, I apprehend that each membranous ampulla will occupy the centre of its osseous envelope, so that at neither extremity of the former will pressure be exerted upon it by the latter.

If under these circumstances the horizontal membranous canal of the left ear were cut, I apprehend that the severed portions would *overlap* each other; so that the extremity of the membranous ampulla of the same canal which is *furthest* from the vestibule would be forcibly driven into the corresponding portion of the osseous ampulla. If this view be correct, it will be seen, by reference to the foregoing argument, that the same signal will have been conveyed to the brain as if the head had moved to the right; that is, warning will have been given to the muscles whose function it is to counteract a motion of the head to the right, to bring themselves into action; whence we might expect that a motion of the head to the left would ensue. As soon as this motion has been completed, however, it is to be anticipated that the sudden and perhaps violent motion of the poor animal under the pain of the operation would make this part of the membranous labyrinth oscillate in the contrary direction, so as to drive the membranous ampulla of the same canal into the opposite extremity of its osseous sac, and thus the signal to move the head to the right would be given.

In this way, I think, may be accounted-for the alternate motion of the head from right to left and from left to right which is stated to have resulted from cutting the left horizontal canal of the pigeon. We may see also how that further result of the experiment might be anticipated which is related to have occurred—that is, that the pigeon would by degrees learn to disregard the anomalous indications of its left ear, and rely wholly on those of the right ear alone, which preserved their normal character.

On the other hand, the cutting of both the horizontal canals would destroy all the means with which nature has provided the animal for ascertaining and measuring the direction and extent of the motions to right and left of its head, and would thus leave it in that state of incapacity to control those motions which is described by M. Flourens.

The effect of cutting the several vertical canals was, for the most part, similar in kind to that of cutting the horizontal canals, though more violent in degree; and the explanation in all the different cases is in its main features the same.

When the ears are perfect, the effect of throwing the head back, upon the principles already explained, would be to force the extremity *nearest* to the vestibule of each posterior vertical ampulla into the corresponding portion of the surrounding osseous ampulla, and thus would be given a signal upon which, subject to the disposition of the controlling will, the muscles by which the head is moved *forwards* would be called into play.

On the other hand, when either of the last-named membranous canals is cut, on the principles above laid down, the effect would be to throw the end furthest from the vestibule of its ampulla into the corresponding portion of the osseous envelope; so that in the latter case a signal would be given of a character opposite to that given in the former; *i. e.* the tendency would be to make the animal fall backwards.

The mode in which, when both the posterior vertical canals were cut, the animal showed a disposition to turn its head upside down so as to rest the top of it on the ground, may be accounted for by supposing that in this way it placed in equilibrium the membranous ampullæ of the canals in question.

The mode of explanation in the case of the anterior vertical canals is obviously the same, *mutatis mutandis,* as in the case last considered.

If the views above set forth be correct, it is evident that we may look upon the membranous labyrinth in the light of a seventh sense*, by which intelligence of the amount and direction of the motions of the head are communicated to the mind or subordinate governing principle. That there is a necessity for some such special provision as regards the motion of the head is sufficiently obvious when we reflect that we cannot judge of the position of the head with regard to surrounding objects in the way in which we can judge of that of the hand, the foot, or any part of our frame which can be contemplated by the eye. It might have been anticipated that the muscular effort necessary to move the head in a given direction would have afforded a sufficiently accurate measure of the effect produced by such effort. I think that M. Flourens's experiments prove conclusively that this is not so, and that a much more refined mode of measurement and adjustment has been provided for us—one, in fact, which takes cognizance of the effects actually produced, and not merely of the efforts made to produce them.

It will probably have been observed, however, that the mode of adjustment, so far as hitherto explained, is in one respect defective. To indicate fully motion in space, regard must be had to six directions, viz. right, left, backwards, forwards, upwards, downwards. Admitting that the membranous canals satisfy our requirements as to the first four directions, how are those for the last two provided for?

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* The sense of muscular exertion being counted as one.

Upon this point I observe that the head cannot be moved up or down without a corresponding motion of the whole or of a large part of the body, for which a very considerable muscular effort is necessary in order to counteract or control the effect of gravity. It may very well be that such increased effort affords a satisfactory measure of the motion up and down, although a similar criterion as regards the horizontal motions would not be sufficiently exact.

I am inclined to think that it is at least one function of the nervous filaments expanded within the membranous sac and utricle to indicate the fact of motion generally, and that they may aid in measuring the vertical movements of the head—their operation in this respect being superseded, as regards the horizontal motions, by the more delicate apparatus afforded by the ampullæ. Any such action of the nerves of the sac and utricle must, of course, be enhanced by the cretaceous otolithes attached to them.

My remarks on this branch of the subject I shall conclude by pointing to the two following cases illustrative of it.

Every one who has had opportunity to observe the development of children in early infancy, must be aware that there is a time at which, although the child is able to maintain its head erect for a few moments, any attempt to change its position is followed by a wild movement of the head, partaking of the character of that described as taking place in M. Flourens's pigeons when all the canals had been cut.

The explanation of this circumstance I take to be, that although the child is able to keep its head erect, and has strength to move the head in different directions, yet it has not so mastered the indications afforded by means of the semicircular canals as to enable it to regulate the motion.

On the other hand, it is not uncommon to meet with persons of middle age, and, still more, with those advanced in life, who are subject to a nervous affection, under the influence of which, although ordinarily they can command the motions of the head like other persons, yet occasionally, and for a brief interval, they appear to lose control over them, the head moving involuntarily.

In explication of this peculiarity, I give from M. Flourens's second memoir his account of the demeanour of a rabbit, one of whose canals had been cut:—

"Dans leur plus grande violence les oscillations de la tête sont très étendues: ces oscillations s'affaiblissent ensuite peu à peu; un moment avant de cesser, *il n'y a plus qu'un léger tremblement qui représente tout à fait le tremblement de la tête qui s'observe dans certains vieillards.*"

Affections such as those last referred to I conceive to arise from paralysis (it may be only partial) of the semicircular canals of *one* ear.

III. I now propose to consider the question whether the functions above described exhaust the purposes of the membranous labyrinth—in other words, whether the membranous labyrinth actually forms part of the organ of hearing.

That, in man and those animals which possess a cochlea, all aërially conveyed sounds are perceived through the agency of the cochlea alone I think there cannot be the smallest doubt. The construction of the tympanal membrane, the bones of the ear, and the two foramina opening from the tympanal cavity into the labyrinth, abundantly prove that motion of the fluid in the cochlea from the round aperture towards the oval aperture, and *vice versá*, is the special effect which aërially conveyed waves are calculated to produce; and even if the nervous filaments of the membranous labyrinth hung loose in the perilymph which surrounds the latter, I cannot see that they would be in any way affected by such motion of the fluid in the cochlea. Still less can this be the case in the actual position of the extremities of the nervous filaments *within* the membranous labyrinth.

But it is not so clear that the nerves within the membranous labyrinth are not affected by undulations propagated through the bone of the skull—as, for instance, when a musical box is placed on the top of the head; or rather it is not so clear whether these nerves do not, under the circumstances supposed, aid in the production of that sensation which we attribute to sound.

I am strongly inclined to take the negative view of the question last stated, and to regard the cochlea on the one hand, and the canals and membranous labyrinth on the other, as totally independent organs which, for constructive and, it may be, for other purposes, are locally connected—just in the same way as the ear and the nostril are connected, though the former is in no degree ancillary to the sense of smell*. This, no doubt, is tantamount to the assumption that animals destitute of a cochlea are incapable of the perception of sound. It is to be observed, however, that it is not denied that when a sounding body is excited, animals in its neighbourhood which are possessed of sac and utricle only, or of those appendages and semicircular canals, receive a signal by which their conduct is regulated. All that is contended for is that such creatures are destitute of any thing corresponding to that affection of the mind which we designate as the hearing of sound.

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* Mr. Wharton Jones testifies to a characteristic difference between the nerves of the cochlea and those of the membranous labyrinth. I do not desire, however, to urge too far this consideration.

Some writers, indeed, maintain that the sense of hearing is merely a refinement of the sense of touch. To this view of the subject I cannot subscribe. A table may vibrate under the influence of undulations which, when brought to bear upon the ear by means of a rod resting on the table, will produce the sensation of hearing. If, under the same circumstances, the table be touched with the finger, the nerves of the finger will be excited by the same vibrations; nevertheless we do not *hear* through the tips of our fingers.

As regards the effect produced by sounding bodies upon the nerves of the membranous labyrinth, whether in animals provided with a cochlea or those destitute of that adjunct—as, for instance, in fishes—I am quite disposed to admit that it may be merely a refined example of the sense of touch*; but the perceptions excited in the human subject through the ear—and the same no doubt must in a degree apply to all animals endowed with a cochlea—appear as distinctly *sui generis* as are those derived through the eye, the nostril, or the palate.

6 New Square, Lincoln's Inn,
January 15, 1870.

P.S.—The following account relating to the nervous apparatus of the ampullæ strikingly illustrates their adaptation to the performance of the delicate functions I have ascribed to them:—

"Dans les ampoules, Max Schultze a découvert, s'élevant hors de la surface interne de cet épithélium [that of the lining membrane of the ampullæ through which the nerves penetrate], des crins élastiques roides tout-à-fait particuliers. . . . . Ils sont beaucoup plus longs que les crins ciliaires des cellules de mica, ... fragiles, et se terminent en pointe très-fine. De petits crins de ce genre, fins et roides, sont évidemment et à un haut degré propres à suivre les mouvements du liquide, et, par suite, à produire une excitation mécanique dans les cordons nerveux implantés dans leurs bases, dans l'épithélium mou. . . . . .

"Les tumeurs épaisses, situées dans les vestibules où viennent se terminer les nerfs, présentent, d'après Max Schultze, le même epithélium dans lequel sont insérées les fibres nerveuses, mais point de crins, ou seulement de très-courts"†.

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* The fact of the antennæ of certain classes of Articulata, through which they are endowed with an exquisite sense of touch, being connected with what have hitherto been regarded as the organs of hearing, is strongly confirmatory of this view.

† *Théorie Physiologique de Musique*, &c., par H. Helmholtz. Traduit par M. G. Queroult. Paris, 1868: p. 172.

From the same work I take this further extract:—" La théorie des sensations auditives qui précède a été confirmée d'une manière intéressante par les observations et les expériences de V. Hensen sur les organes de l'ouïe chez les Crustacés. Ces animaux ont de petits sacs moitié fermés, moitié ouverts à l'exterieur, où les otolithes nagent librement dans une humeur aqueuse, et qui sont surmontés de petits crins rigides particuliers, reliés par leurs extrémités aux otolithes, formant une série ordonnée par ordre de grandeur. . . . On trouve aussi, chez beaucoup de crabes, de petits crins tout-à-fait analogues sur les parties libres du corps, et qui doivent être considérés comme les organes de l'ouïe. Ce qui le prouvent pour les crins extérieurs c'est en partie l'analogie de leur construction avec les crins des otolithes, en partie la circonstance qu'ils se relient aux nerfs de la même manière, et partent de la même souche que dans les otolithes. Enfin Hensen a trouvé que l'ouïe persistait après l'extirpation des sacs des otolithes dans le *Mysis* [the Opossum Shrimp], l'animal ne conservant que les crins extérieurs des antennes "*.

Without questioning the action of sonorous undulations upon the organs referred to, I would suggest a doubt as to whether the sensations so produced can in any correct sense of the term be designated as sensations of hearing.

Recurring to the subject of the human ear, I would remark that the aërial waves emanating from a sounding body must necessarily produce an oscillation to and fro of the head in a vertical plane passing through the source of sound. Upon the principles I have above endeavoured to unfold, it is conceivable that this oscillation, however minute, may produce such an effect on the nerves of the ampullæ as in some degree to indicate the direction from which the sound proceeds—a view which many have entertained—although these nerves, as I conceive, do not in any way contribute to the sensation of hearing.

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* *Théorie Physiologique de Musique*, &c., par H. Helmholtz, p. 187.